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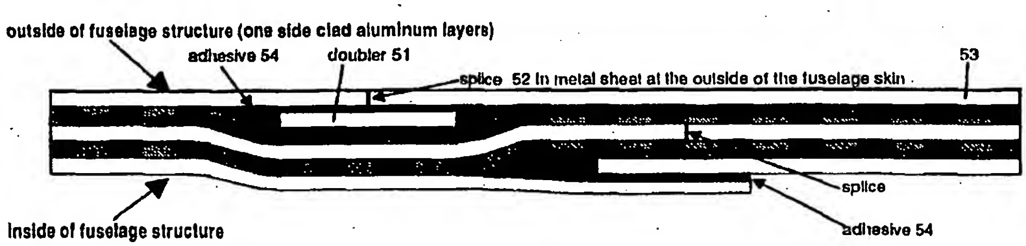
(54) Title: METHOD FOR MAKING A LAMINATE AND LAMINATE OBTAINABLE BY SAID METHOD



(57) Abstract

The invention pertains to a method for making a laminate comprising at least the following steps: placing a first metal sheet on a form tool or a substrate, placing an adhesive layer on top of the first metal sheet, placing a second metal sheet on top of the adhesive layer such that at least one of the metal sheets overlaps at least one edge of the other metal sheet, applying heat and pressure to the thus obtained stack, where during the application of pressure at least one of the metal sheets is bent towards the plane of the other metal sheet. Thus, complicated structures can be optimized for a certain application and, besides, manufactured in one go using comparatively inexpensive tools.

Method for making a laminate and laminate obtainable by said method

The invention pertains to a method for making a laminate or laminated panel comprising at least the following steps:

placing a first metal sheet on a form tool or a substrate,

placing an adhesive layer on top of the first metal sheet,

placing a second metal sheet on top of the adhesive layer such that at least one of the metal sheets overlaps at least one edge of the other metal sheet,

applying heat and pressure to the thus obtained stack (i.e. mainly or solely to the side of the stack facing away from the form tool or the substrate).

Such a method is known from, for instance, US 5,429,326, which is directed to a laminated body panel for aircraft applications. The panel comprises at least two metal layers with an adhesive layer provided therebetween. The metal layers are composed of two or more sheets or sections which are generally coplanar and separated by a so-called splice or splice line. It is described how a splice in a first metal layer is parallel to but laterally spaced from the splice in a second, adjacent metal layer. By using this staggered stacking the maximum width of the laminate is no longer restricted to the width of the metal sheets or sections, which width is limited to approximately 165 cm by present manufacturing technology.

A further advantage resides in that the spliced laminates of US 5,429,326 surprisingly have an increased residual strength (i.e., strength after the laminate has been damaged by, for instance, impact) for loads parallel to the splices when compared with unspliced laminates.

However, it is desirable (and in many cases prescribed by safety regulations) to cover (part of) the splice with a so-called doubler to prevent exposure of the splice to environmental conditions and to increase the tensile strength (for

This method advantageously exploits the low bending stiffness of the uncured laminate, i.e., the stack of metal and adhesive layers prior to the application of heat and pressure, and the fixation or freezing of the deformations in laminate by, e.g., curing, evaporation of a solvent contained in the adhesive, or cooling below the Tg of the adhesive. With the invention, each metal layer is forced to take on the form of the stack directly beneath it.

Preferably, the metal sheet is displaced over a distance which is of at least about the same order of magnitude as the thickness of the adhesive layer or the thickness of the adhesive layer and a metal sheet.

Figure 2 shows a structure obtained via the method of the present invention with only one autoclave cycle (duration: approximately 1 hour) at conventional pressure and heat levels, viz. 5 bar and 120 °C. A first aluminium doubler (21; 2024-T3 having a thickness of 0.3 mm and having been subjected to an alkaline degreasing treatment followed by etching or anodising and application of a primer) is placed on a form tool (not shown) having a flat and smooth surface. Three aluminium layers (22; again, 2024-T3 having a thickness of 0,3 mm and having been subjected to the same treatment as the doubler (21)) and two adhesive layers (23; each consisting of three layers (0°-90°-0°) of unidirectional S2-glass fibres in F185 ex Hexcel) in between the aluminium layers (22) are stacked on top of the doubler (21), with the splice (24) in the aluminium layer (22) nearest the doubler (21) positioned halfway along the width of the doubler (21). A second doubler (25) is placed over the splice in the aluminium layer farthest from the first doubler (21). An adhesive (26; AF 163-2K ex 3M) is present between the doublers (21, 25) and the aluminium layers (22). Subsequently, heat and pressure are applied (on the side marked "inside of fuselage structure"). During this the spliced laminate is bent around the doubler (21), and the adhesive layers (23) and the adhesive (26) are cured. At the locations of the doubler (21) the layers of the spliced laminate are curved to form a fully (aerodynamic) flat surface with the doubler (21).

that the clad layer is also present in splice shaped as overlap (41). In the aircraft industry it is preferred not to bond metal together in cladded zone, since these bonds are of importance to the integrity of the primary structure of the airplane and the interaction between the clad and the adhesive in an corrosive environment may result in unfavourable behaviour. Further, the adhesive fillets (26 and 43 in Figures 2 and 4, respectively) which normally have a width of 6 - 10 mm will remain visible on the outside of the unpainted fuselage skin.

In view of the above reasons, the configurations shown in Figs. 2 and 4 are less desirable in the mentioned "bright-skin aircraft." However, both problems (clad in the bonding zone and broad, visible fillets) are solved by a further and preferred embodiment of the present invention shown in Figure 5. Instead of placing the doubler (51) directly on a form tool, it is stacked on a substrate (mounted on a form tool), in this case a metal layer (53) consisting of at least two metal sheets or sections separated by a splice (52). The metal sheets constituting the metal layer (53) are cladded only on the side contacting the form tool and will become an integral part of the laminate. During the application of pressure and heat the doubler (51) and the metal layer (53) will not deform, whereas the rest of the spliced laminate (metal layers and prepregs) are bent around the doubler (51).

The actual bonding zones are embedded in the laminate and do not contain any clad. Also, only a very thin (0.1 - 0.6 mm) splice (52) is visible on the outside of the skin of the fuselage structure.

Additional advantages of this configuration are obviating the need for anodizing and priming only a small edge (i.e., the overlap in Fig. 4) of the ouside of the aluminium metal sheets when a polished fuselage skin is desired (those parts of the metal sheets that are in contact with an adhesive have to be anodised and primed) and, in painted aircraft, the avoidance of damage to the bonding zones during (periodic) paint removal and.

It should be noted that the bends in the metal sheet may include both an elastic and a plastic deformation component. Which of the components prevails will depend largely on the material types, the dimensions, and the manufacturing conditions.

The adhesive layers are, preferably, reinforced with (glass) fibres. If splices are present in the laminate, part of the (glass) fibres should preferably bridge the splices and they should generally be uninterrupted adjacent to the splice lines. The fibres may be oriented individually or in groups, in one direction or in several different directions, depending on the loading conditions of the structure. Preferably, at least about half of the fibres extend perpendicular to the splice lines in adjacent metal layers. In a particularly preferred embodiment, about half of the fibres are oriented in 0° (longitudinal) direction, while roughly the other half are oriented in a 90° (transverse) direction. Alternatively, about one third of the fibres may be oriented at 0° and about two thirds at 90°, or about two thirds may be oriented at 0° and about one third at 90°.

The adhesive layers preferably comprises synthetic polymers. Examples of suitable non-thermoplastic polymers are epoxy resins, unsaturated polyesters, vinyl esters, phenolic resins, and thermoplastic resins. Suitable thermoplastic polymers are, e.g., polyarylates (PAR), polysulphones (PSO), polyether sulphones (PES), polyether imides (PEI), or polyphenylene ethers (PEE), polyphenylene sulphide (PPS), polyamide-4,6, polyketone sulphide (PKS), polyether ketones (PEK), polyether ether ketone (PEEK), and polyether ketone-ketone (PEKK). As mentioned above, in addition to the adhesive that is part of the adhesive layers, adhesives (see, e.g., the adhesives denoted by numerals 17, 26, 36, 43, 54) are used locally in other parts of the laminates. In principle, all adhesives suitable for use in the adhesive layers are also suitable for use as 'local' adhesive.

sheets is bent towards and preferably also substantially extends in the plane of the other metal sheet. It is preferred that an additional adhesive is applied in the area where the metal sheets overlap.

These laminates can exhibit a flat surface in spite of the presence of "irregularities" such as doublers, are relatively inexpensive, for they can be manufactured in one production cycle using comparatively inexpensive tools, allow the production of spliced panels with a reduced weight, and exhibit ply-drop-off configurations with high strength. Also, testing of these laminates revealed that they have substantially the same mechanical properties as conventional metal-polymer laminates (viz., excellent fatigue resistance, high residual strength, fire resistance, corrosion resistance, etc.).

A further advantage resides in that the interference of the splice details (e.g., splice lines, doublers) with the structural details of the aircraft design (e.g., location of stringers, shear cleads, frames windows, doors) can be kept to a minimum, because the minimum thickness step in the new concept is smaller than that for conventional production methods (compare Fig. 1 with Fig. 3) and also smaller than 0.5.- 0.6 mm, which is the maximum thickness step that may, in practice, still be bridged by stringers.

The invention also pertains to a constructional component for a verhicle, spacecraft, or aircraft comprising a laminate according to the invention and to an aircraft comprising the said laminate.

It should be noted that EP 502 620 discloses the overlaying of additional sheets or doublers of a superplastically formable material on a main sheet of material (prior to superplastic forming) in regions where additional strength is required or where excessive elongation is to occur during forming which, otherwise, would result in the region being locally thinned or weakened (see, e.g., the abstract and Fig. 7 of the said patent application). Metal-polymer

Claims:

1. Method for making a laminate comprising at least the following steps: placing a first metal sheet on a form tool or a substrate, placing an adhesive layer over of the first metal sheet, placing a second metal sheet over of the adhesive layer such that at least one of the metal sheets overlaps at least one edge of the other metal sheet applying heat and pressure to the thus obtained stack, characterized in that during the application of pressure at least one of the metal sheets is bent towards the plane of the other metal sheet after which the form of the metal sheets is fixed.

2. Method according to claim 1, characterized in that the second metal sheet is bent towards the plane of the first metal sheet.

3. Method according to claim 1 or 2, characterized in that the surface of the form tool or substrate facing the stack is substantially smooth and/or curved.

4. Method according to any one of claims 1-3, characterized in that the adhesive layer comprises at least one prepreg.

5. Method according to any one of claims 1-4, characterized in that the the first metal layer is a doubler and the second metal layer comprises a splice which is positioned at or near the middle of the first metal layer.

6. Method according to any one of claims 1-4, characterized in that the substrate comprises at least one metal layer and at least one adhesive layer.

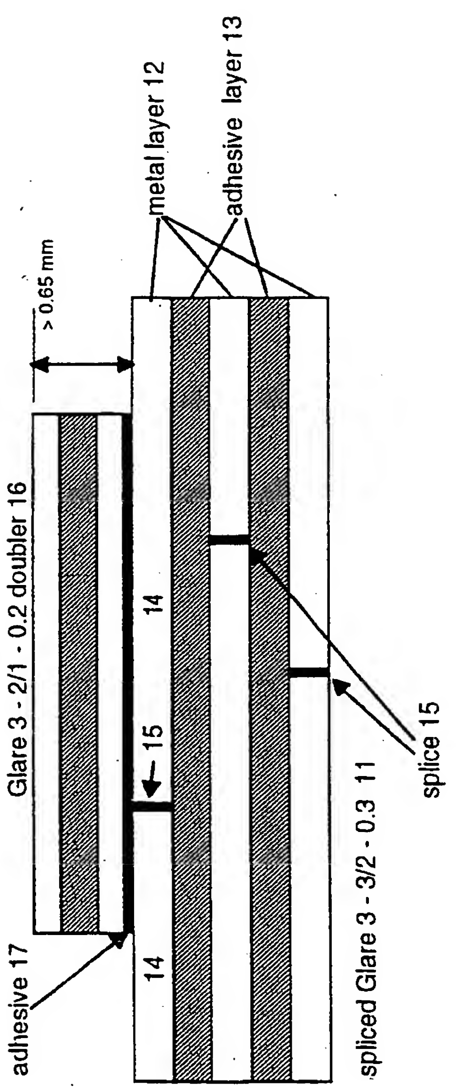


Figure 1

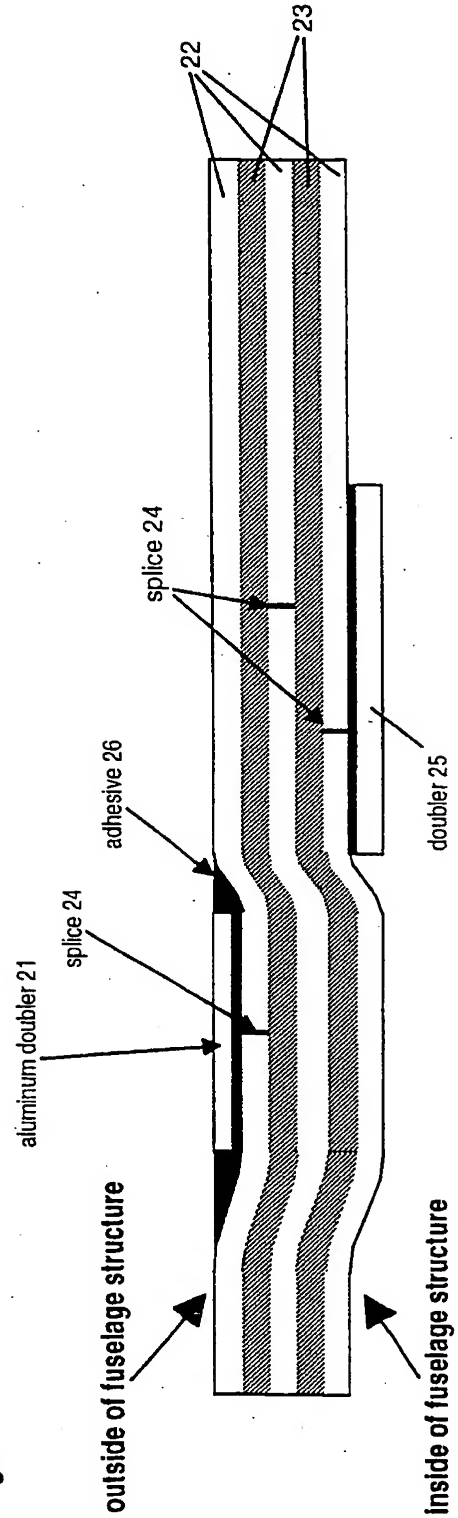


Figure 2

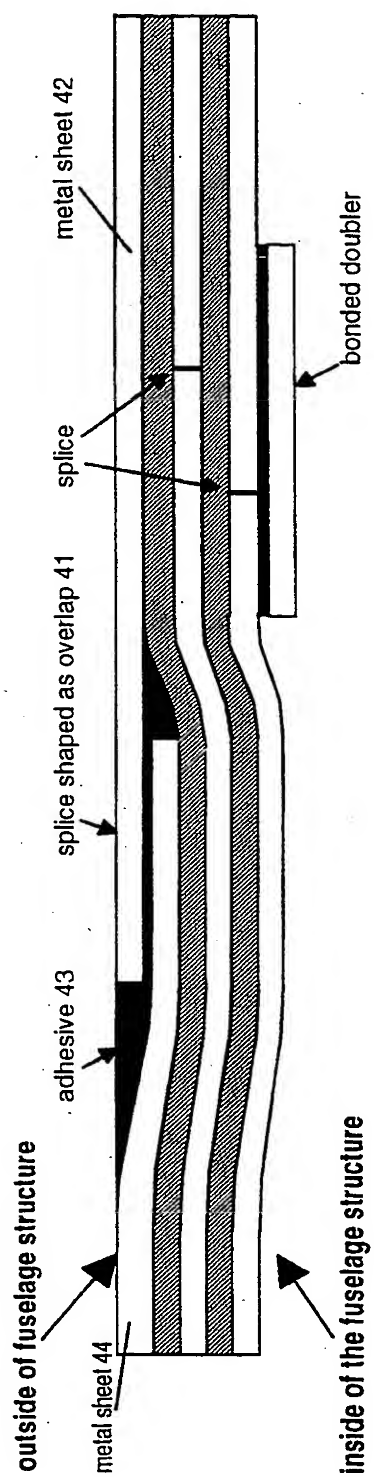


Figure 4

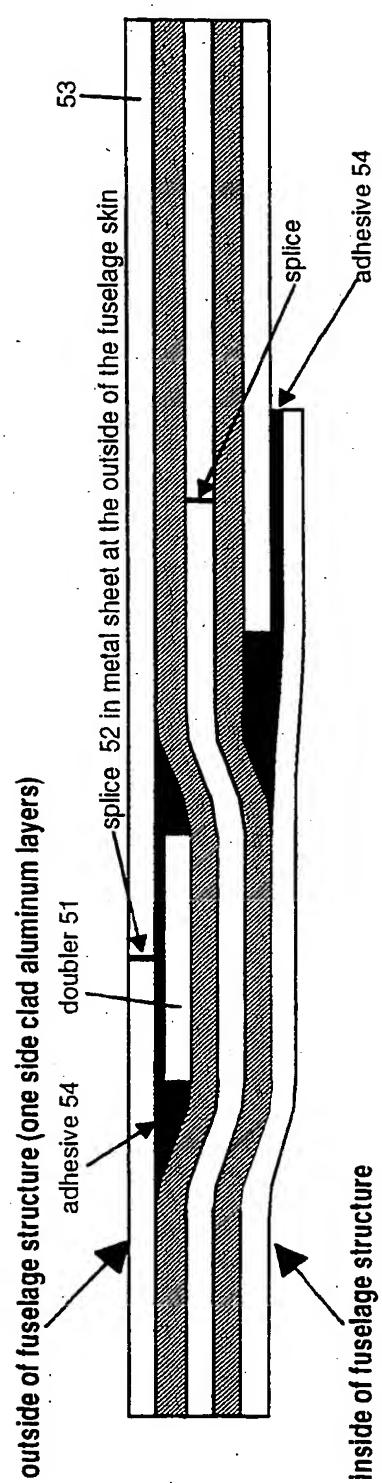


Figure 5

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 98/03173

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US 5429326 A	04-07-1995	DE 69314175 D	30-10-1997
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